REMARKS

Claims 1-4 and 9-29 remain in the application.

The Examiner has objected to the disclosure on a number of specific grounds. The amendments to the disclosure are believed to remove the objections.

The Examiner has rejected Claim 14 under 35 U.S.C. §112, ¶2 for indefiniteness because of the lack of antecedent basis. The claim has been amended to correct the problem.

The Examiner has rejected Claim 1, 2, 5-9, 12-15, and 17-20 under 35 U.S.C. §102(e) as being anticipated by US Patent 5,770,098 issued to Araki et al. (hereinafter Araki). Base Claims 1 and 17 have been amended to require that the etching gas mixture contains no carbon monoxide. Araki's invention emphasizes the importance of a large fraction of CO, as evident from his disclosure at page 5, lines 50-58 and page 7, lines 41-48. Accordingly, Araki does not anticipated these claims.

The Examiner has rejected Claims 1-8, 10, 12, 13, 15, and 16 under 35 U.S.C. §102(e) as being anticipated by US Patent 5,811,357 issued to Armacost et al. (hereinafter Armacost). Claim 1 has been amended to require that the heavy fluorocarbon gas be hexafluorobutadience. Accordingly, Armacost does not anticipate these claims.

The Examiner has rejected Claims 1, 5-9, 12-15, and 17-20 under 35 U.S.C. §102(e) as being anticipated by US Patent 6,069,092 issued to Imai et al. (hereinafter Imai). Base Claims 1 and 17 have been amended to require selectivity to nitride. In contrast, Imai is primarily concerned with selectivity to photoresist and does not discuss selectivity to nitride. His structure is formed over a planar silicon layer, not in the presence of nitride and certainly not over a corner nitride corner as required in some of the claims. Accordingly, Imai does not anticipate these claims.

Additionally, Claim 15 requires that oxide corners be exposed during processing, an example of which is the timed counterbore trench etch of FIGS. 9-11 described on pages 15 and 16. In contrast, all of Araki, Armacost, and Imai rely upon a patterned resist layer to protect the

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oxide corners during etching. A new set of claims, generally of the scope of the original Claim 15 have been added though the base claim does not require selectivity to nitride.

The Examiner has rejected Claims 10 and 11 under 35 U.S.C. §103(a) as being obvious over Imai in view of Wang et al. (US Patent 6,074,959, hereinafter Wang). Claim 11 has been canceled with its restrictions incorporated into Claim 10.

First, this rejection could be removed by timely refiling this application as a CPA, thereby removing Wang as a reference under §102(e).

Second, these claims are dependent upon claims believed to be in allowable form and should therefore also be allowable.

Thirdly and more importantly, the rejection is traversed since the reference does not provide an enabling disclosure of how to achieve the claimed 25% process window and indeed does not suggest that it is possible.

Wang provides a number of process variations, but she claims only ±5%, far below the claimed 25%. That is, there is no suggestion in the art that a 25% process window is possible.

Wang suggests an optimized process window, but with a significantly different chemistry of a hydrofluoropropane and argon, not the hexafluorobutadiene and xenon of the claim. She therefore does not enable the achievement of the desired and claimed process window for the claimed chemistry. Whether Wang teaches the importance of the obtaining a large process window is not relevant to the enablement requirement. Imai may *arguendo* teach the chemistry but does not suggest that it has the desired process window. In fact, Imai teaches specific recipes and their results only for C_4F_8 and C_5F_8, and there is no suggestion that these recipes achieve the desired process window nor a suggestion that these recipes blindly adapted for hexafluorobutadiene would provide the claimed process window.

Accordingly, Claim 10 is additionally allowable.

The Examiner has provisionally rejected Claims 1-13, 14, and 15-20 under 35 U.S.C. §101 for same type double patenting of Claims 1-13, 17, and 19-24 of US Patent Application 09/405,869. The cited application is a continuation in part of the present application. When

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otherwise allowable subject matter is indicated in the present application, the double patenting will be addressed.

In view of the above amendments and remarks, reconsideration and allowance of all claims are respectfully requested. If the Examiner believes that a telephone interview would be helpful, he is invited to contact the undersigned attorney at the listed telephone number, which is on California time.

Respectfully submitted,

Charles S. Guenzer
Registration No. 30,640
(650) 566-8040

Date: 17 May 2001

Correspondence Address
Patent Counsel
Applied Materials, Inc.
P.O. Box 450A
Santa Clara, CA 95052

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Serial No. 09/276,376

Version with markings to show changes made

Replace paragraph at page 1, lines 9 and 10 with:

This application is related to Serial No. 09/276,311 [_________ (Applied Materials Docket #2073-P4)] concurrently filed March 23 [24], 1999 by Hung et al.

Replace paragraph at page 5, lines 2-16 with:

An example of an inductively coupled plasma etch reactor is the Inductive Plasma Source (IPS) etch reactor, which is available from Applied Materials and which Collins et al. describe in U.S. Patent Application, Serial No. 08/733,544, filed October 21, 1996 and in European Patent Publication EP-840,365-A2. As shown in FIG. 3 [2], a wafer 30 to be processed is closely supported on a cathode pedestal 32 supplied with RF power from a first RF power supply 34. A silicon ring 36 surrounds the pedestal 32 and is controllably heated by an array of heater lamps 38. A grounded silicon wall 40 surrounds the plasma processing area. [.] A silicon roof 42 overlies the plasma processing area, and lamps 44 and water cooling channels 46 control its temperature. In the described embodiments, the silicon roof 42 is grounded, but it may be separately RF biased for other applications. The volume of the vacuum processing chamber is about 23 liters. The temperature-controlled silicon ring 36 and silicon roof 42 may be used to scavenge fluorine from the fluorocarbon plasma. For some applications, fluorine scavenging can be accomplished by a solid carbon body, such as amorphous or graphitic carbon, or by other non-oxide silicon-based or carbon-based materials, such as silicon carbide.

Replace paragraph at page 6, lines 9-19 with:

Optical emission spectroscopy (OES) is a conventional monitoring process used for end-point detection in plasma etching. An optical fiber 70 is placed in a hole 72 penetrating the

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chamber wall 40 to laterally view the plasma area 74 above the wafer 30. An optical detector system 76 is connected to the other end of the fiber 70 and includes one or more optical filters and processing circuitry that are tuned to the plasma emission spectrum associated with the aluminum, copper, or other species in the plasma. Either the raw detected signals or a trigger signal is electronically supplied to the controller 52, which can use the signals to determine that one step of the etch process has been completed when [as] either a new signal appears or an old one decreases. With this determination, the controller 52 can adjust the process recipe or end the etching step according to the power levels set primarily in the source power supplies 66, 68.

Replace paragraph at page 8, lines 20-29 with:

Hung et al. in concurrently filed U.S. Patent Application, Serial No. 09/276,311 [__________, ("PROCESS FOR ETCHING OXIDE USING HEXAFLUOROBUTADIENE AND MANIFESTING A WIDE PROCESS WINDOW," Applied Materials Docket #2073-P4)], disclose the advantageous use of the heavy fluorocarbon gas hexafluorobutadiene (C_4F_6) in combination with argon or possibly other noble gases for etching oxide in the IPS chamber of FIG. 2. This patent application is incorporated herein by reference in its entirety. Hexafluorobutadiene has the chemical structure illustrated in FIG. 4. The combination of C_4F_6 and large amounts of Ar is shown to produce highly isotropic etching with acceptable selectivity to corner nitride in SAC and related applications. Importantly, the process is shown to exhibit a wide process window.

Replace paragraph at page 10, lines 9-20 with:

Xenon (Xe) demonstrates a substantially different behavior from argon (Ar) when used as a diluent gas in fluorine-based oxide etching. A series of preliminary experiments were performed in the IPS reactor in which a mass spectrometer [[???]] was attached to the chamber while a mixture of C_4F_6 and either helium (He), Ar, or Xe was admitted to the chamber and excited into a plasma under fairly realistic excitation power and pressure. The relative intensities

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for the ions C^+, F^+, CF^+, CF_2^+, and CF_3^+ are shown in FIG. 5 for the three diluents He, Ar, and Xe. No attempt was made to ionize neutral radicals. These data show a significantly different distribution for the ionic species dependent upon the noble gas. Helium is totally different except for the C^+ ion. Xenon relative to argon favors the formation of the heavier ion CF_2^+, which has been ascribed to be responsible for polymer formation. Somewhat similar results are obtained with C_4F_8 although this fluorocarbon produces only about half the amount of C^+ relative to the other ionic species.

Replace the three paragraph at page 11, line 22 to page 13, line 22:

Two series of experiments were performed which measured oxide and nitride etch rates for blanket structures, that is, unpatterned oxide and nitride layers. The experiments used a combination of C_4F_6 and either Ar and Xe. The selectivity to nitride is plotted in FIG. 8 for the two diluent gases as a function of the diluent flows. The two diluents exhibit significantly different behavior. The nitride selectivity for Ar is highest at low Ar flows and decreases at higher argon flow. However, the cited C_4F_6 patent to Hung et al. demonstrates that in narrow geometries such as SAC structures, a higher argon flow is required to prevent etch stop. On the other hand, the data of FIG. 8 shows that nitride selectivity for Xe rises with increasing Xe flow. As a result, no etch stop and high nitride selectivity can both be attained with high flows of Xe. The data of FIG. 8 are derived from separately measured oxide and nitride losses. The oxide losses (oxide etch rate) for the two diluents do not significantly differ, both decreasing about 30% from 20sccm to 500sccm of the diluents. However, the nitride loss with Ar remains substantially constant from 100sccm to 500sccm while that with Xe drops by almost a factor of three between 20sccm and 500sccm.

Replace the two paragraphs at page 12, line 5 to page 14, line 22 with:

Another series of experiments were performed using the recipe of TABLE 1 but with two different Xe flows, 15 and 150sccm.

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	Initial Recipe
C_4F_6 Flow (sccm)	10
Xe Flow (sccm)	15--150
Inner Source Power (W)	300
Outer Source Power (W)	1250
Bias Power (W)	1400
Pressure (mTorr [mT])	7
Roof Temp. (°C)	200
Ring Temp. (°C)	270
Cathode Temp. (°C)	+10
Backside He Pressure (Torr [T])	7

TABLE 1

In one set of experiments, the process etches a hole through 0.8μm of oxide. An overlying photoresist layer is patterned with a 0.5μm hole, and the oxide is underlaid with a nitride layer. At 15sccm of Xe, the hole profile angle is about 88°, and a slight loss of nitride is observed. At 150sccm of Xe, the hole profile angle decreases [increases] to 86°, but no nitride loss is visible. In another set of experiment, the SAC structure is etched with a bottom hole width of 0.36μm and a side gap of 0.18μm beside the gate structure. Although the corner nitride selectivity is acceptable at the lower Xe flow, corner nitride etching virtually disappears at the higher Xe flow. The etching was not carried to completion of the via hole. However, no polymer residue is observed in the narrow side gap. A related experiment was performed on a structure having a gap of 0.13μm between the gate structures, the gate structures having a height as measured by the nitride of about 0.45μm. The recipe follows that of TABLE 1 with a C_4F_6 flow of 20sccm and a Xe flow of 15sccm. Substantial but acceptable nitride corner faceting is observed. Importantly,

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no etch step is observed through the completion of the narrow hole etching.

The etch rates observed with the recipe of TABLE 1 are considered to be somewhat low for commercial applications. Accordingly, the recipe was modified to that presented in TABLE 2, which has a higher pressure of 45 milliTorr as well as somewhat higher powers and C_4F_6 flow, all intended to increase the etch rate.

	Baseline SAC Recipe
C_4F_6 Flow (sccm)	16
Xe Flow (sccm)	350
Inner Source Power (W)	360
Outer Source Power (W)	1600
Bias Power (W)	1800
Pressure (mTorr [mT])	45
Roof Temp. (°C)	180
Ring Temp. (°C)	270
Cathode Temp. (°C)	+10
Backside He Pressure (Torr [T])	7

TABLE 2

As measured in a 0.4μm-wide, 1.2μm-deep hole, the oxide etch rate is 600nm/min. The profile angle is approximately 89°, but there is some barreling over 1.8μm. When a SAC structure is used, in a narrow side gap beside the gate structure, some tapering is manifested as a bottom corner oxide. The nitride corner selectivity is too high to measure.

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Replace the two paragraphs at page 15, lines 14-31 with:

After the completion of the counterbore deep via etch, the via mask is removed, and a photoresist layer 90 is deposited over the top of the oxide 86 and patterned according to the intended trench. In the timed counterbore process, the trench etch is timed to extend approximately half-way through the oxide layer 86 to form an idealized trench 92, indicated by dotted lines in FIG. 9. During the timed counterbore trench etch using a non-oxide selective etch chemistry, the underlying nitride stop layer 84 prevents further etching of the underlying material [layer]. As noted before, a subsequent single metal filling sequence fills both the bottom portions of the vias 88 and the trench 92 after whatever nitride 84 remains at the bottom of the vias is removed by a post-etch.

Unlike the more conventional counterbore etch, the timed counterbore trench etch does not rely upon another nitride stop layer formed between upper and lower portions of the oxide layer 86 to define the bottom of the trench 92 since the fluorocarbon etch can be made highly selective to nitride. Thus, the timed counterbore potentially simplifies both the deposition and the etching procedures in forming a dual-damascene structure. However, the timed counterbore process has not been found to be very successful in the past because of severe faceting of the oxide corners surrounding the via holes. Faceting is exhibited in silicon oxide by approximately 45° facets at the corner caused by the unfavorable geometry of an exposed 90° oxide corner during an oxide etch.

Replace the two paragraphs at page 16, line 17 to page 17, line 19 with:

A C_4F_6/Xe recipe summarized in TABLE 3 has been developed in the IPS chamber for the timed trench etch in the counterbore dual-damascene process.

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	Timed Trench Recipe
C_4F_6 Flow (sccm)	15
Xe Flow (sccm)	15
Inner Source Power (W)	300
Outer Source Power (W)	1500
Bias Power (W)	1000
Pressure (mTorr [mT])	7
Roof Temp. (°C)	200
Ring Temp. (°C)	270
Cathode Temp. (°C)	+10
Backside He Pressure (Torr [T])	10

TABLE 3

This recipes produces a structure similar to that illustrated in FIG. 10. The taper angle for the via is about 86½°. A similar recipe using C_4F_8/Ar produces significantly greater tapering and reduced sidewall height.

Greater amounts of xenon can used. However, at 150sccm of Xe, the height of the via sidewall is reduced. On the other hand, substantially less Xe produces very poor results. With no xenon, the unacceptable structure of FIG. 11 is produced. Furthermore, polymer forms both on the trench shelf, which is not bad, but also on the bottom of the via hole, indicating etch stop [[???]].

Replace all claims with:

1. (Amended) A process for etching an oxide layer in the presence of a nitride layer,

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comprising the steps of:

flowing into a plasma reaction chamber a gas mixture comprising a first amount of hexafluorobutadiene [a fluorine-containing gas] and a second amount of xenon and including substantially no carbon monoxide, wherein a ratio of said second amount to said first amount is at least one;

applying a first level of RF power to a pedestal electrode supporting a substrate containing said oxide and nitride layers [non-oxide layer]; and

exciting said gas mixture into a plasma to thereby selectively etch said oxide layer to said nitride [non-oxide] layer.

2. (Amended) The process of Claim 1, wherein said oxide layer overlies said nitride [a non-oxide] layer and said ratio is at least ten, to thereby etch said oxide layer selectively to said nitride [non-oxide] layer.

3. (Amended) The process of Claim 2 [1], wherein said nitride layer [non-oxide] comprises a nitride formed into a corner feature.

Please cancel Claims 5-11.

14. (Amended) The process of Claim 12, wherein said applying [biasing] steps applies at least 1600W to said pedestal electrode normalized to a 200mm wafer.

17. (Amended) A process of etching an oxide layer selectively to an underlying nitride layer, comprising the steps of:

flowing into a plasma reaction chamber a gas mixture comprising a first amount of hexafluorobutadiene and a second amount of xenon and including substantially no carbon monoxide;

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exciting said gas mixture into a plasma in a region of said chamber remote from a wafer supported on a pedestal electrode; and

applying RF power to said pedestal electrode to create a DC bias.

18. (Amended) The process of Claim 17, wherein said RF power is applied in an amount of 1500W normalized to a <u>200mm</u> [200nm] wafer.

Please add the following new claims:

21. (New) A process for etching an oxide layer preformed with holes extending downwardly from a top surface thereof, comprising the steps of:

flowing into a plasma reaction chamber a gas mixture comprising a first amount of a fluorine-containing gas and a second amount of xenon, wherein a ratio of said second amount to said first amount is at least one;

applying a first level of RF power to a pedestal electrode supporting a substrate containing said oxide and non-oxide layer; and

exciting said gas mixture into a plasma to etch said oxide layer, wherein corners of said oxide layer at tops of said holes are exposed during the process.

22. (New) The process of Claim 21 carried out in the presence of a nitride layer, wherein said plasma etches said oxide layer selectively to said nitride layer.

23. (New) The process of Claim 22, wherein said oxide layer overlies said nitride layer.

24. (New) The process of Claim 21, wherein said fluorine-containing gas comprises a fluorocarbon.

25. (New) The process of Claim 24, wherein said fluorocarbon consists of at least four

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carbon atoms, at least an equal number of fluorine atoms, and no more than two hydrogen atoms.

26. (New) The process of Claim 24, wherein said fluorocarbon is hydrogen free.

27. (New) The process of Claim 25, wherein said fluorocarbon is selected from the group consisting of hexafluorobutadiene, hexafluorocyclobutene, hexafluorobenzene, octafluorocyclobutane, and octofluoropentadiene.

28. (New) The process of Claim 27, wherein said fluorocarbon comprises hexafluorobutadiene.

29. (New) The process of Claim 28, wherein said oxide layer overlies a nitride layer and said plasma etches said oxide layer selectively to said nitride layer.

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